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Abstract

It has been argued that imitation might facilitate social interactions and may increase affiliating emotions between individuals. Hence imitation recognition can be considered as the recognition of matching actions performed by other individuals with those of the self and also importantly it is thought to foster sensitivity to social contingencies. Imitation recognition has mainly been associated only with humans.

Although phylogenetically distant from humans, dogs might provide a useful model for understanding the evolution of imitation recognition and its effects on affect. It has already been previously demonstrated that though it is not their characteristic way of learning socially, dogs are capable of imitation. Therefore, imitation recognition may also play a role in the social interactions of dogs.

In order to investigate this question, an experimental set up was designed so that two dogs (subject and partner) would work simultaneously on two identical apparatuses for which they had been previously trained to operate either using their paw or mouth. Subsequently, it was studied whether dogs could locate food more successfully in a cooperative task, based on gazing cues given by a partner who had performed a matching action rather than when the cues were given by a partner that used a non-matching action.

The present study provides evidence that dogs are able to follow conspecific gaze in order to locate hidden food. Moreover, that it depends on the social context and previous interactions between dogs. Namely if both subject and partner had used the same action during the simultaneous working phase, it affected the dogs' outcome in a subsequent two-way object choice task as subjects made a higher number of correct choices and also above chance levels and took less time to approach the bowls.

Henceforth, this study contributes to better understand how dogs interact and cooperate.

Keywords: Domestic dog (*Canis familiaris*); Imitation recognition; Two-way object choice task; Conspecific gaze following; Cooperation.

Resumo

Tem-se argumentado que a imitação pode facilitar interacções sociais e pode aumentar emoções afiliativas entre indivíduos. Deste modo, o reconhecimento da imitação pode ser considerado como um indivíduo reconhecendo as suas próprias acções nas acções realizadas por outros indivíduos. Pensa-se ainda inclusivamente que promova uma maior sensibilidade às contingências sociais, no entanto o reconhecimento da imitação tem sido sobretudo apenas associado aos seres humanos.

Embora filogeneticamente distante da espécie humana, o cão doméstico pode ser um modelo útil para a compreensão da evolução do reconhecimento de imitação e os seus efeitos sobre empatia. Já foi demonstrado anteriormente que embora não seja a sua forma característica de aprendizagem social, os cães são capazes de imitar. Assim, o reconhecimento da imitação pode desempenhar também um papel importante nas interacções sociais dos cães.

Para investigar esta questão, concebeu-se uma experiência de modo a que dois cães (indivíduo focal e parceiro) trabalhassem simultaneamente em dois aparelhos idênticos para os quais tinham sido previamente treinados usando a pata ou a boca. Subsequentemente avaliou-se a hipótese dos cães numa tarefa cooperativa serem capazes de localizar alimento, com base no olhar do parceiro para um determinado local, com maior taxa de sucesso caso tivessem previamente realizado a mesma acção.

O presente estudo demonstra que os cães são capazes de seguir o olhar de um conspecífico de forma a localizar alimento escondido. Além disso, demonstrou-se que esta capacidade depende do contexto social e interacções prévias entre estes. Deste modo, caso ambos, indivíduo focal e parceiro, tivessem usado a mesma acção durante a fase inicial, maior o número de escolhas correctas feitas pelo indivíduo focal não feitas ao acaso, bem como, este levava um menor tempo deste a aproximar-se das taças.

Este estudo contribui para uma melhor compreensão da interacção e cooperação entre cães.

Palavras-chave: Cão doméstico (*Canis familiaris*); Reconhecimento de imitação; Tarefa de escolha entre dois objectos; Seguimento do olhar de conspecíficos; Cooperação

Table of Contents

1 Introduction

1.1 Social learning through imitation

While most would agree that imitation is a form of social learning which, by observing a model, allows an individual to copy its specific body movements and, consequently, to reproduce the same result, there has been a still unresolved debate about the neurological and cognitive mechanisms underlying imitation (Huber, Range et al. 2009). For some, imitation is an automatic process that relies on learnt associations (Heyes 2011) or even on a shared neurological basis that is activated by perceiving others' actions as well as controls the actions of the self (so-called mirror neurons (Heyes 2010)). Others argue that imitation is an inferential process that evaluates the efficiency of the observed methods based on its constraints and outcomes (Gergely, Bekkering et al. 2002; Range, Viranyi et al. 2007).

Again others defend that the term imitation should only apply when an individual understands the goals and intentions of the model, and relate imitation to goal comprehension, intentionality and theory of mind [1] (Heyes 2001; Nielsen 2006). Imitation has been suggested to provide the bases for language learning, skill acquisition, socialization and enculturation, and hence, is a subject of great interest in areas such as evolution, cognition, neurosciences, ethology and even robotics (Heyes 2001; Meltzoff and Decety 2003).

The debate on mechanisms has been coupled with the question whether and which animal species are capable of imitation. Those using the most cognitively advanced definition argue, that imitation is an exclusively human ability and is unlikely to be observed in any nonverbal animal (Tomasello, Kruger et al. 1993). Others, relying on rather behavioural definitions of imitation, have found several examples in non-human animals. One remarkable imitation study was done on archer fish (*Toxotes chatareus*) (Schuster, Wöhl et al. 2006). The authors proved that archer fish are able to precisely copy the body movements of a conspecific demonstrator and even learn about the relation between the movements of the demonstrator and the movements of the insect that they prey on. Another interesting example of imitation comes from Voelkl and Huber's study (Voelkl and Huber 2007) on common marmosets (*Callithrix jacchus*). This study demonstrated that marmosets are able to copy a specific

[1] Note: An individual having theory of mind can be defined as being able to attribute mental states to himself and to others, like for instance: intention, belief, knowledge, ignorance, false belief and so forth Premack, D. and G. Woodruff (1978). "Does the chimpanzee have a theory of mind?" Behavioral and Brain Sciences **1**(04): 515-526.

topography of movements performed by a skillful demonstrator, therefore showing that they are capable of movement imitation. In this task the animals had to retrieve food from a canister that could only be opened using their mouth. The individuals movements were measured through directly tracking the head movement recurring to a frame-to-frame analysis and hence reconstructing its trajectory of during the task. Results showed that animals who had the chance to observe a demonstrator, besides copying the use of the same body part as the model for solving the problem, also copied details of the movement of the demonstrator's head in time and space.

Conversely, the animals that did not have an opportunity to observe a model followed different movement patterns when opening the canisters. This was the case, even if they had the chance to open a canister repeatedly, which could have led to enlightening and thus converging with the trajectory of the model's movements. Consequently, these and similar studies provide remarkable evidence that non-human species are capable of imitation in the sense that they are able to precisely copy the body movements and orientation demonstrated by a model.

1.2 Imitation and its emotional effect

As an interesting outcome of the debate on the neurological mechanisms underlying imitation, more recently it has been proposed that a Perception Action Mechanism (PAM) which allows an observer (subject) to perceive the actions and state of another individual through the neural and bodily representations of the subject itself may support not only imitation (matching actions) but also a rudimentary form of empathy (matching emotions) (Preston and de Waal 2002). This means that when the subject relates to the state of another individual, the neural representations of similar states of the subject are automatically and unconsciously activated. Moreover, the authors argue that the more similar and socially close two individuals are, the easier it will be for the subject to relate, leading to the enhancement of its matching motor and automatic responses. Importantly, (Preston and de Waal 2002) PAM correlates with the mirror neurons' discovery (Pellegrino, Fadiga et al. 1992) which link perception and action at the cellular level. Neurological structures involved both in afferent and efferent processes have been suggested to be the basis for emotional contagion, the lowest level of empathy, when an observer's emotions correspond to a model's emotional state without the observer being able to distinguish its own emotions from other's (Preston and de Waal 2002). It has been proposed that emotional contagion is shared by human and non-human animals. For

instance, (Church 1959) and (Watanabe and Ono 1986) have shown that rats and pigeons, respectively, would get distressed as a consequence of perceiving distress in a conspecific and would suppress their conditioned behaviour, if the conditioned stimulus caused a pain response in other individuals.

Perception-action mechanisms are then directly connected to motor perception (Wolpert, Ghahramani et al. 2001), so one can assume that the perception action mechanism associated to empathy can also be associated to motor mimicry. This way, it is possible to directly link emotional contagion and imitation (de Waal 2008). Keeping in mind that, as discussed earlier, more advanced cognitive processes may play a role in imitation and, similarly, also more sophisticated forms of empathy are likely to include interaction between emotional and cognitive perspective taking systems Keeping in mind that, as discussed earlier, more advanced cognitive processes may play a role in imitation and, similarly, also more sophisticated forms of empathy are likely to include interaction between emotional and cognitive perspective taking systems (Edgar, Nicol et al. 2012), one can assume that imitation and empathy are interconnected as various levels.

One of the first examples demonstrating the link between emotions and imitation is facial mimicry. Human adults involuntarily and instantly react to various facial expressions such as happy/angry faces and the contraction of the corresponding muscles can be detected with EMG on their faces (e.g. (Sato and Yoshikawa 2007)). Facial mimicry does not depend on a cognitive process and can appear within a one second interval (rapid facial mimicry - (Doherty 1998)) as opposed to voluntary responses. Emotional contagion has been connected to facial mimicry (matching of the observed facial expression) but the mechanisms behind it are not quite clear yet (Hofelich and Preston 2011). Studies with primates have shown that rapid involuntary facial mimicry is not restricted to humans. Chimpanzees, with no prior training, spontaneously match videos with conspecific facial expressions (Parr 2001), and also orangutans rapidly mimic open-mouth faces of their playmates within a one second time interval (Davila Ross, Menzler et al. 2008).

There is another context with which we think to demonstrate the connection between imitation and empathy. (Chartrand 1999) showed that a tendency to imitate seems to increase liking between individuals in a simple interactive situation where participants were placed in a room with another person (confederate) and were asked to describe pictures in turns. Without the participants' knowing, the confederates were asked either to imitate the participants' postures, movements and mannerisms or to maintain a neutral posture, different

from the participants' posture. At the end of the experiment, participants were asked to answer a few questions about the other participant (confederate), to rate how much they liked the other person and to describe how the interaction had gone. Results showed that the participants, who were imitated by confederates, liked them better and considered that the interaction had gone better in comparison to the participants that were not imitated by their confederates. Therefore, it seems when someone is being imitated she/he will tend to like more the one who imitates her/his actions. Such unconscious, emotional processes may, in turn, be essential for the establishment and regulation of social interactions, coordination and cooperation with others (de Waal 2008). Thus, imitation is hypothesized to facilitate social interactions by increasing the levels of connectedness and liking between people, bringing people closer together and leading to mutual care (Iacoboni 2009). Mutual imitation between individuals is also an important part in communication; in particular individuals tend to display the same type of posture/gestures in a conversation and this is more likely to be observed between individuals with higher liking between them. Indeed it is often observed that a listener adopts the same postural conformation as the speaker, thus showing more connection between the two persons. For instance, if the speaker furrows a brow or rubs the chin, the listener will do the same (Meltzoff and Decety 2003).

In humans this phenomenon develops quite early. Pre-verbal children engage in synchronic imitation already at the age of six to eighteen months: they copy what others do with a set of objects by choosing to play with the same toy at the same time, though not always using the same movements (Nadel 1986; Asendorpf and Baudonnière 1993). According to our above definition of imitation, this would rather be considered as stimulus enhancement than imitation, since the children neither precisely copy the specific actions demonstrated by the model nor reproduce the same result (Tomasello 1990; Carpenter, Call et al. 2002; Nielsen 2006). Still, interestingly enough, in this situation children seem to recognize and to enjoy the copying behaviour by gazing at the partner more times, laughing more and by having more interactive episodes when being copied (Nadel 1986; Asendorpf and Baudonnière 1993). Some studies show that children tend to engage in more playful behaviour towards an imitator (Nadel 1986; Meltzoff 1990; Asendorpf, Warkentin et al. 1996).

Another study (Meltzoff 1990) showed that the interactions of 14-month-old children with adults can be influenced by imitation in a similar way. The authors intended to test if the infants could recognize when they were being imitated and the emotional value associated with this experience. One of the experiments subjected 14-month-old infants to two adults,

one of whom imitated everything the baby was doing whereas the second adult imitated what a previous baby had done. The results showed that the infants could distinguish between the two adults' actions and identified the one who was imitating them. They looked for longer periods and engaged in more testing behaviour towards the adult who was imitating them. More than 50% of the 76 infants tested exhibited testing behaviour towards the adult who imitated their actions. By testing behaviour the authors referred to the child engaging in a variation of activities, that is, the children made sudden and unexpected movements, apparently in order to confirm if the adult would do the same. Additionally, the infants found not only interesting or important that an adult was imitating them but also responded with positive emotions to it like smiling more. Similar results were obtained with (Asendorpf, Warkentin et al. 1996) 18-month-old children (Asendorpf, Warkentin et al. 1996.

Little is known, however, whether non-human animals can recognize when they are being imitated and especially whether they also feel more affiliatively toward their imitators. One of the few studies (Nielsen, Collier-Baker et al. 2005) provided the first evidence of imitation recognition in nonhuman animals on a captive born chimpanzee (*Pan troglodytes*). The experimental setup included four conditions, namely the experimenter either imitated every movement of the chimpanzee or performed one of three control actions ((1) contingent, non-matching; (2) non-contingent, non-matching and (3) no action at all). A control test was performed to check if there were not any peculiarities about the imitation displayed by the experimenter during the first test that would have lead the chimpanzee to behave differently during the imitation versus the control conditions. Results showed that the chimpanzee displayed testing behaviours solely during the imitation condition. Thus, only when being imitated the chimpanzee displayed a series of actions that had not been seen either previously or in any other test trials. Moreover, the chimpanzee repeated behaviour more often during the imitation condition, as well for a significantly longer period of time in comparison to the other conditions.

More recently, (Haun and Call 2008) also investigated imitation recognition in eleven individuals belonging to four species of non-human great apes. The authors were able to replicate the results obtained by (Nielsen, Collier-Baker et al. 2005) following the same experimental setup. Results showed that nine out of eleven animals exhibited testing behaviour at least once in the contingent, matching action, whereas for the other conditions the number of animals engaging in testing behaviour was considerably lower. The animals spent also more time with testing behaviour in the imitation condition (around 16,5%) than in

the three other conditions. Hence, these studies provide good evidence that imitation recognition characterizes not only humans but also non-human great apes.

Finally, (Paukner, Anderson et al. 2005) tested ten pigtailed macaques (*Macaca nemestrina*) on their ability to recognize when a human experimenter imitated their actions towards an object. Two experimenters were facing the subject who had access to a wooden cube that could be freely manipulated. One of the experimenters imitated the monkey's cube-directed actions in a matching, contingent manner, whilst the second experimenter performed different actions though contingent with the subject's actions. Results showed that subjects demonstrated a clear visual preference for the imitator during manipulating the cube. In contrast to the studies aforementioned, the subjects did not engage in testing behaviour. Hence, the authors suggest that monkeys might display imitation recognition at an implicit level. (Nadel 2002) suggested that implicit imitation recognition might lead to increased level of visual attention while explicit imitation recognition is characterized by the subjects displaying behaviours that test the imitator, like exhibiting non-stereotyped behaviour while looking at the imitator.

In sum, the studies presented here provided clear evidence that imitation recognition can be found in other species besides the human species, though it may be expressed in different way, either more explicitly through the demonstration of testing behaviours or in a more implicit way through increased visual attention. No evidence exists, however, that recognition of being imitated would lead to more affiliative emotions in non-human animals.

1.3 Following gaze to locate food as a potential measure of interindividual affiliation

Gaze following occurs when one individual follows the line of sight of another individual that observes a point in space. Moreover, gaze following can be adaptively advantageous and plays an important role in social animals since it might allow individuals to detect food, predators and even to detect social interactions among group mates (Itakura 2004). Also interestingly, gaze following, particularly when talking about joint attention (gaze following towards an attention focus such as an object), is thought to be connected to the early development of language and theory of mind (Baron-Cohen 1994; Gómez 2009), hence seeming to play an important role in understanding mental states like attention and intention of others (Tomasello, Carpenter et al. 2005). In order to recognize what another individual is observing, there is the necessity to perceive the other individual's body and eye orientation

and from this interpret the direction of the gazing, which in turn depends on mimicking one's perspective relating a determined observable and physical point-of-view with its own internal mental state (Shepherd 2010).

Furthermore, it has been suggested that pre-verbal children recur to gaze following in order to understand what other individuals refer to (Tomasello 1995) and as it plays a central role in referential communication, it has been argued that gaze following develops earlier in humans than in other species and acting like a predecessor to linguistic communication (Senju and Csibra 2008). Throughout the literature it is already possible to find some examples reporting gaze following in non-human animal species, namely in ravens (*Corvus corax*) (Bugnyar, Stöwe et al. 2004), apes (Bräuer, Call et al. 2005), domestic goats (*Capra hircus*) (Kaminski, Riedel et al. 2005), northern bald ibises (*Geronticus eremita*) (Loretto, Schloegl et al. 2010), red-footed tortoises (*Geochelone carbonaria*) (Wilkinson, Mandl et al. 2010) and in wolves (*Canis lupus*) (Range and Virányi 2011) which leads us to argue about its evolutionary origin.

It is important to mention though that there are different levels of gaze responsiveness, namely at a more basic level simple detection of the gaze of others, secondly following the direction of others' gaze adapting the same head/eye orientation to look in the same direction of another individual, and finally the more difficult level following the gaze of another individual and identifying the target of attention. We will only focus on the third level. Commonly researchers recur to two-way object choice tasks to study the ability of following the gaze of others towards a target and also to investigate the main paradigm behind it which is how non-verbal communication is perceived. Hence, although as mentioned above it has already been reported that many non-human species are able to follow gaze, most of them including apes, fail to use gaze cues given by a human or a conspecific to locate hidden food because because they do not understand the sharing/cooperative message of the gazing cue (Fitch, Huber et al. 2010). Though, dogs seem to be the exception. One possible explanation is the Emotional Reactivity Hypothesis proposed by (Hare and Tomasello 2005) which states that the process of domestication lead to selection against fear and aggression towards humans in some species like the dog. Moreover, the process of domestication seems to have lead dogs for instance to develop an unusual ability to read human social communicative and cooperative behaviours like gazing or pointing gestures representing a case of convergent evolution with humans. This ability might have resulted from previously existing cognitive abilities like 'reading' conspecific behaviour that were adapted to solve a new set of social problem involving humans. Furthermore, (Hare and Tomasello 2005) also argue that flexible

forms such as human cooperation and communication depend on a human-like temperament and its evolution might set the background for more complex forms of social cognition. Hence, investigating in which ways dogs communicate, cooperate and have developed their particular social skills provide us further insight into the evolutionary processes behind human cooperative interactions and communication.

It also has already been shown that dogs are able to locate hidden food following cues given by a conspecific informant. This was studied by (Hare and Tomasello 1999) using a two-way object choice paradigm where a conspecific demonstrator, placed equidistantly between two opaque containers, would look towards the container that had been baited previously with food. Results showed that four out of ten dogs chose correctly the container at least 17 out of 24 trials making it above chance level and also importantly the gender, breed and age factors did not seem to play an effect. It is also important to mention that controls rule out that dogs used olfactory cues to locate the food inside the pots. Although this study is not able to explain the mechanisms of how the domestic dog perceive the visual gaze of others, for instance, inferring the other individual's intentional or mental state, it definitely contributes to the discussion of gaze following evolution since it provides evidence coming from a species phylogenetically distant from human and non-human primates.

Interestingly, it has been suggested in the human literature that gaze following and imitative behaviours might be correlated as they both can be observed during infant development (Carpenter, Nagell et al. 1998). Moreover (Meltzoff 2007) mentions two studies that set these two behaviours as timely congruent. First, it has been observed that 14-month-old infants are able to recognize the correspondence between their own actions and the matching actions performed by an adult and infants do it so by looking for significantly longer periods and by smiling more at an adult that imitates them. Second, 14-month-old infants turn and selectively look towards a determined target when an adult looks at it as well infants look for longer periods at the target versus a situation where the adult is not looking. Although in this instance the author does not correlate directly the two behaviours nor if the mechanisms underlying them have the same basis still one can argue until which extent both behaviours are linked. Also importantly, one should mention that children do not just 'want to see what others see' but attempt to share attention with others (joint attention), that is, children are able to experience what others see but are also able to acknowledge that others are doing it seeing as well, hence sharing an intention to cooperate and communicate with others (Tomasello and Carpenter 2007). Therefore, gaze following also seems to set ground to establish a link

between individuals, such as through communication, and also like imitation, gaze following can be related to affiliative behaviours such as cooperation.

Some authors view gaze following as imitation (Nagai 2005; Hoffman, Grimes et al. 2006) by considering that one individual shifts its gaze towards a particular location in space by replicating an action done by another individual. Though it might be debatable if it can be considered 'true' imitation since the individuals that are following the gaze are not truly learning a new behaviour as gazing is already part of their repertoire and also because the motor patterns of the model can be different form the ones of the subject (Triesch, Jasso et al. 2007). Anyhow, the connection between gaze following and imitation might imply that the gaze following behaviour might emerge in a similar way and for similar reasons as imitation. It is even argued that for certain forms of imitative behaviour to emerge it might be a pre-requisite for gaze following to develop first (Kumashiro, Ishibashi et al. 2003).

Hence, it is definitely pertinent to investigate to which extent there is a correlation between imitation, imitation recognition and gaze following and moreover to investigate its evolution by studying different species like for example the domestic dog.

1.4 The dog (*Canis familiaris*) as a model for studying behaviour

What makes the domestic dog (*Canis familiaris*) a good model for studying behaviour?

Dogs have the potential to model particular aspects of social interactions, including social learning, a category in which imitation fits within. Consequently, it makes dogs perfect candidates for studying behaviour, namely because of (1) the selection of their wild ancestors, like the wolf, for highly social behaviour, and for adapting to various environments; (2) domestication; and (3) the naturalistic socialization with humans during ontogeny (Kubinyi, Pongrácz et al. 2009).

Although there are not many examples in literature, dogs are probably also a good model for studying empathy. Dogs evolved from wolves which are known for being animals with a complex social structure and that participate in joint activities, and leading one to argue that might have some empathy capacity for socially close individuals. Additionally, the selection of previously existing cognitive abilities like 'reading' conspecific behavior for increasingly more complex cognitive capacities during the process of domestication, might have provided the basis for the development of empathy in dogs, especially when considering the human-dog relation (Silva and de Sousa 2011).

When studying imitation in non-human animals there are some aspects that should be accounted for. When comparing dogs to other animals like apes, the possibilities of designing an experiment for testing social learning are more restricted. This is partly due to the fact that dogs have more rigid motor patterns, thus being limited in producing finer motor movements that could reflect their actual perceptual capacities and cognitive processing (Osthaus, Lea et al. 2005). It is then important to mention that according to the definition of imitation, which implies that an individual learns about a new motor aspect of behaviour, there might be some theoretical/practical difficulties in telling apart imitation from other forms of social learning. Given the restricted set of movements that many animals can do (paw/mouth use) while manipulating an apparatus (e.g. which has a handle), it might be complicated for the experimental setup to satisfy the requirements assumed by the previous imitation definition. However, one can consider a broader definition, in which small details regarding the handling of an apparatus like pushing a handle to the same side should be considered as evidence of imitation (Kubinyi, Pongrácz et al. 2009).

Imitation has already been previously studied in the domestic dog, though not always obtaining clear evidences of voluntary imitation, that is, evidences that imitative behaviour should be under the control of intentional mechanisms (Range, Huber et al. 2011). Namely, (Topál, Byrne et al. 2006; Huber, Range et al. 2009) Do-as-I-do studies provided some evidence about dogs being able to reproduce faithfully novel object-oriented actions (‘functional’ matching of human actions) that cannot be considered as part of the behavioural repertoire of the dogs, meaning that new actions were learned through imitation. However, when it comes to body-oriented actions results were not so clear, since the subjects appeared to generalize their understanding of copying and not match the novel demonstrated actions. Also (Tennie, Glabsch et al. 2009) were not able to find evidence of imitation for intransitive actions like lying down on belly or lying down laterally, demonstrated by another dog, even when dogs were well trained. This led the authors to argue that dogs would only be able to learn by observation if the actions observed are associated with an object in the environment (transitive actions).

Similarly, (Miller, Rayburn-Reeves et al. 2009) used a bidirectional control procedure, in which observer dogs would have to watch a demonstrator dog manipulating a screen door either to the left or to the right. Results showed that dogs imitated the direction demonstrated more than in the control where dogs just observed the screen door move without any demonstrator manipulating it. Although, authors acknowledged that the observed results could

be due to the fact that dogs were able to learn which direction the door moved rather by emulation than imitation. Observer dogs seemed to match the direction to which move the door in the absence of a demonstrator. Also authors mentioned the possibility of observational conditioning, which means the dogs might have established a Pavlovian association between the direction towards which the door moved and food.

Even though the previous works were unable to provide clear evidence of imitation in dogs, (Range, Viranyi et al. 2007) have presented the first study with positive results, namely through a selective-imitation task, in which focal individuals observed a demonstrator dog pressing a rod with its paw for food. In order to control if subjects had preference for an action to manipulate the experimental apparatus, a group of naïve dogs worked with it in the absence of a demonstrator. Dogs preferentially used their mouths to pull down a wooden rod in order to retrieve a food reward. Thus, in a second phase of the experiment, two experimental groups were allowed to observe a demonstrator dog that had been trained to manipulate the wooden rod using solely its paw to solve the problem. Hence, the demonstrator dog would use an 'inefficient' action to perform the task. Results showed that dogs exhibited a clear preference for using the paw (83.33%) even though if it was not the preferred action. Although if the demonstrator displayed a constraint like having a ball in its mouth only 21,05% of the subjects would copy the action used by the demonstrator. Therefore, this study provided a clear evidence for action imitation in dogs. Subjects used a less probable action to solve the problem merely after a demonstration from a conspecific.

More recently, (Range, Huber et al. 2011) also provided more evidence about dogs being able to imitate, more particularly, that dogs are subject to automatic imitation. The experiment consisted of having two groups of dogs, each with five individuals, and that were trained in an initial phase, prior to testing, to solve a task that implied sliding a door from a wooden box in order to retrieve a treat, using either their paw or head. One of the groups was then given a task in which dogs would have to open the sliding door using the same method (either head or paw) as their owner (compatible group), whereas in the second group, the dogs had to use a different method from the method the owner used to open the door (incompatible group). Results showed, that dogs from the compatible group, needed less trials to reach the learning criterion (in this case, responding correctly in 17 out of 20 trials; 85%) than the dogs from the incompatible group that had to counter-imitate their owners. Indeed, dogs from the incompatible group needed around 265 trials versus the 83 trials needed by the dogs from the compatible group. This data not only proved that dogs are able to imitate, since dogs learned

to solve a task using the same action as their owners (in the case of the compatible group), but they also showed a tendency to imitate a demonstrated action, showing a propensity to be subjected to automatic imitation [2] like humans are.

Hence, the two previous studies mentioned before, provide evidence that dogs, even though it may not be their most frequent way of learning socially, are capable of imitation. Still there is no evidence that dogs are able of imitation recognition. Therefore, the main goal of this work is to study the ability of dogs (*Canis familiaris*) to recognize that they are being imitated when performing a particular action on an apparatus, and if it leads to a more positive interaction and higher cooperation with an individual who performed a matching action on a similar apparatus in contrast to others who performed different actions. We hypothesise that if dogs are able to recognize imitation, this will affect the outcome in a two-object choice task, that is, dogs will tend to cooperate more and to follow more successfully the gaze of a partner that has beforehand used a matching action versus a partner that used a non-matching action. Also importantly, we hypothesize that the way that dogs interact and perceive conspecifics is context dependent, namely, if dogs are able to recognize imitation, at least at an implicit level, this fact will be very likely to affect dogs preference to follow conspecifics' cues and also affect the way dogs pay attention to these.

2 Methods

2.1 Subjects

A total of 46 dogs (*Canis familiaris*) and their owners participated voluntarily in the study. The sample included 24 females and 22 males, hence having a balanced sex-ratio. Eight dogs had to be excluded from the study because during testing they displayed stress and no compliance to work, and thus the experiment was interrupted. Three other dogs were excluded due to errors by the experimenter. The recruited dogs were well-trained (agility, rescue and obedience training), with ages comprised between one and sixteen years old (mean-age ± SD: 4.45 ± 2.96 years) and from various breeds. Each dog was semi-randomly assigned to a testing group in order to counter balance sex across groups.

[2] Note: Automatic imitation has been defined as a type of stimulus-response compatibility in which a particular movement performed by an individual acts like a stimuli and facilitates an observer to perform the same type of movement, using the same body part as the demonstrator. Plus, automatic imitation interferes with the performance of dissimilar responses Heyes, C. (2011). "Automatic imitation." Psychological Bulletin **137**(3): 463-483.

2.2 Experimental arrangement

The experiments were carried out in a familiar environment to the dogs, in the Clever Dog Lab, Vienna between October 2011 and June 2012. The experimental apparatus had the same design as the one used by (Range, Viranyi et al. 2007) in the selective imitation study on dogs (**Figure 1 A**). Thus, the apparatus consisted of a wooden rod that could be operated by the dogs using either their paw or their mouth by pressing it down (**Figure 1 C** and **D**), respectively, in order to retrieve a food reward from a food container. Only, the food container was adapted in a way that it allowed the dogs to retrieve ten pieces of reward continuously without the experimenter having to replace them every time the rod was pressed down (**Figure 1** B). For this reason, since the experimenter did not have the chance to stop the movements of the apparatus during its operation, the rod was fixed to the floor with strings.

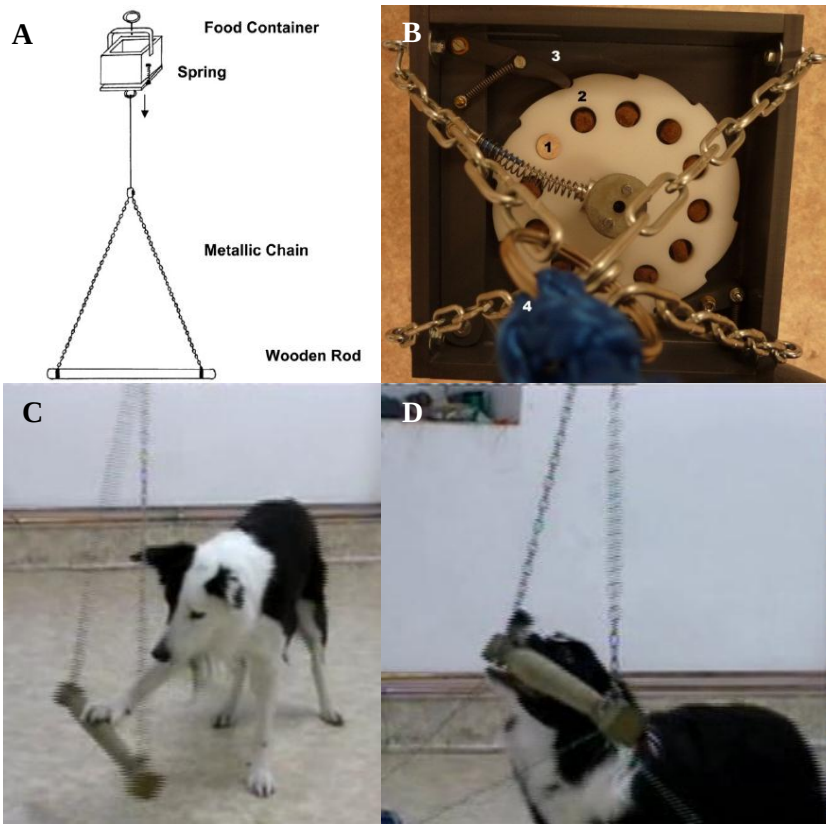

Figure 1 Experimental apparatus and dogs operating it. (A) In order to retrieve a food reward, dogs had to press down a wooden rod using either their paw or their mouth. (Image retrieved from (Range, Viranyi et al. 2007)). (B) Food container. The food container includes: one slot through which the food rewards fall down (1); eleven slots where the food rewards can be placed (2) and the mechanism rotates through the action of a tab (3) that moves whenever the rod is pressed. The food container is hung with a hook to the testing room's ceiling (4). (C) Dog using its paw to press down the wooden rod of the apparatus in order to retrieve a food reward. (D) Dog using its mouth to pull down the wooden rod of the apparatus in order to retrieve a food reward.

Dry food pellets from Royal Canin® were used as reward. All the tests were recorded for later behavioural coding, using four JVC digital cameras placed at each one of the corners of the experimental room.

2.3 Procedures

2.3.1 Preliminary training

All the dogs participating in the study were subjected to a preliminarily training phase. The dogs were trained either to press the rod with their paw or to pull it down with their mouth. Each dog was trained for its preferred action based on its initial approach in operating the apparatus. The owners participated actively in the training and they were allowed to use any method they preferred to achieve this goal (e.g. clicker training). The training phase was completed when the dog was able to perform one of the actions successfully at least five times in a row upon verbal command of the owner standing one meter distant behind the dog. 38 dogs only required one hour training session whereas 8 dogs required two training sessions that took place with no more than a two week interval.

2.3.2 Test

After successfully completing the training phase each dog was submitted to two tests with two phases each. Seven weeks on average elapsed between the training session and the first testing session (range: 1 to 21 weeks). The time between 2 tests was on average 6 weeks (range: 1 day to 20 weeks).

2.3.2.1 Partners

The subjects were tested with two of four possible partner dogs. To play this role, we trained two females and two males to use either solely the paw action or the mouth action to operate the apparatus. One male and one female were trained on each of the two actions. Each subject was tested twice, with two out of four partners that could perform a matching action (MA) or a non-matching action (NMA) (paw or mouth action) and that could either have matching sex (MS) or non-matching sex (NMS) of the subject. **Table 1** depicts subject distribution across the four possible conditions: matching action/matching sex; matching action/non-matching sex; non-matching action/matching sex; non-matching action/non-matching sex.

Table 1 Subject distribution across the four testing conditions in their 2 tests. (MA) Matching Action, (NMA) Non-Matching Action, (MS) Matching Sex, (NMS) Non-Matching Sex.

		Test 1				Total dogs
		MA/MS	MA/NMS	NMA/MS	NMA/NMS	
Test 2	MA/MS		1	6	6	
	MA/NMS	1		9	5	
	NMA/MS	6	2		2	
	NMA/NMS	4	2	2		
						46

2.3.2.2 Phase 1: Imitation recognition

The tests were carried out in an equally divided room (6,55 x 4,90 m) with a see-through fence, where two identical experimental apparatuses were placed (one on each side of the fence – the subject and the partner's compartment) (**Figure 2**). The owner was present in the subject's compartment and the experimenter was standing in the partner's compartment. Both of them positioned themselves behind the dogs and close to the door. Immediately prior to this phase, every subject was retrained once again on their assigned action with the experimental apparatus. The subjects had to press the rod successfully, meaning that they had to get the reward, ten out of ten times before testing.

Each one of the dogs, the subject and partner, were let into the experimental room at the same time through one of two doors, each corresponding to one of the compartments. In the Imitation Recognition Phase the subjects were allowed to work on their apparatus performing the action previously trained while a partner dog was working on its identical apparatus on the other side of the fence. However, firstly the subject was allowed to start working on the experimental apparatus whereas the partner was sent to the apparatus 15 seconds later.

The owners were allowed to encourage their dog to perform the task, but they were not allowed to interfere with the apparatus manipulation, namely pressing the rod to help their dog. Both dogs could retrieve the ten food rewards from their experimental apparatuses and they were allowed to interact with the apparatuses as long as both of them were finished. After a 2-3 minute interval the test was repeated in the same way once again.

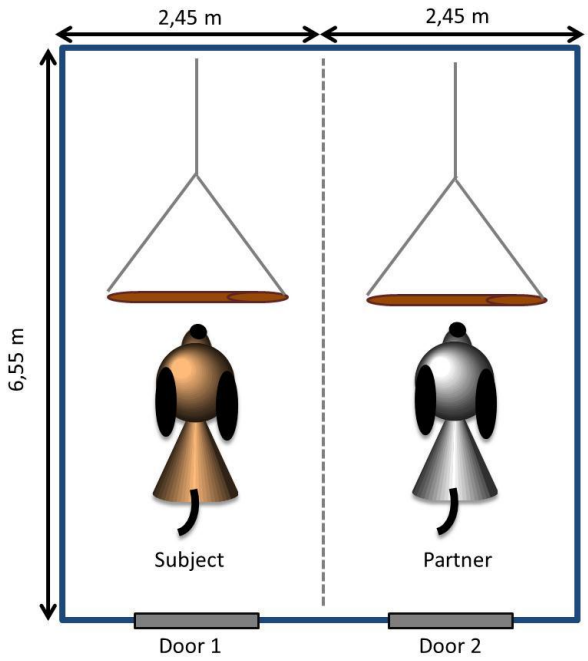

Figure 2 Schematic representation of the experimental set up used in phase one. (Not drawn to scale).

2.3.2.3 Phase 2: Two-way object choice task

In the second phase, the subjects went through a two-way object-choice task where the subject could observe its partner gazing at one of two containers that had been baited with food. The partner was placed in a compartment that was separated from the experimental room with a sliding door that could be operated by the experimenter remotely from behind the subject. The subject was held by the owner that was sitting in a chair 3.20m from the compartment where the partner dog was sitting. After the two dogs were set into position, the experimenter baited one of two bowls that were placed on each side of the partner with 94 cm distance between them (**Figure 3**). During this the owner covered the subject's eyes with her hands to ensure that it could not see which bowl was baited. The experimenter went back to her position behind the subject and instructed the partner to gaze at the baited bowl by signalling it with discrete hand gestures. After the partner dog looked at the baited bowl, the experimenter closed the sliding door and the subject was released to choose a bowl. If the subject failed to choose the baited bowl its owner called it back and/or experimenter picked the baited bowl up and thus the subject was not rewarded. If it chose the baited bowl, the subject was allowed to take the reward. The same procedure was repeated 19 times more. After ten trials there was a 2-3 minute break, and then the test was resumed. Across the 20

trials, the baiting was randomized and counter-balanced between left and right with the restriction that one side could not be rewarded more than two times in a row and this did not happen in the beginning of the test.

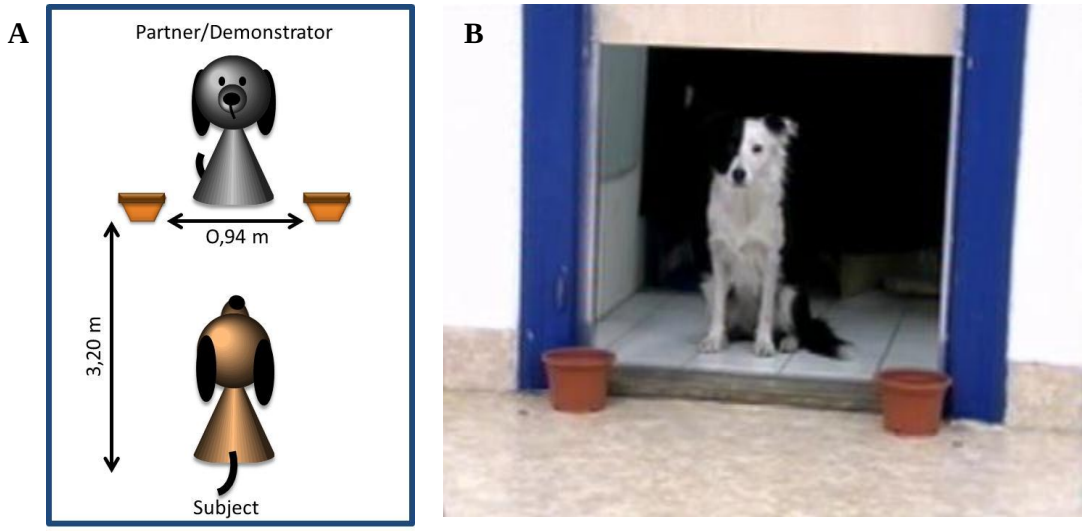

Figure 3 Two-way object choice task. (A) Schematic representation of the experimental set up used in phase two. (Not drawn to scale). (B) Partner/demonstrator standing behind the lifted barrier.

Subjects were distributed across four possible conditions: matching action/matching sex (N=24), matching action/non-matching sex (N=20), non-matching action/matching sex (N=27), non-matching action/non-matching sex (N=21).

2.3.3 Coding

The number of correct choices out of 20 trials and the latency in each trial to make a choice after the dog was released were coded from the videos of Phase 2, using Solomon Software Version: beta 11.10.24.

2.3.4 Statistical analysis

All statistical analyses were done recurring to R version 2.15.1 (2012-06-22) Software. Since all subjects were tested in two out of four possible conditions (matching action/matching sex; matching action/non-matching sex; non-matching action/matching sex and non-matching action/non-matching sex) the data was analysed with Generalized Linear Mixed Models (GLMM). Sex and action were used as fixed effects while individuals were used as random effects. Interactions between sex and action were also considered. GLMM are quite useful for analysing data sets in fields like behaviour, ecology and evolution that often do not follow a

normal distribution and that frequently involve random effects which for instance, non-parametric tests might not account for. Random effects can be defined as factors that are sampled from a larger population and whose parameters are standard deviations of variation among for example, experimental blocks and also importantly account for variation among individuals (Bolker, Brooks et al. 2009).

The number of correct choices made by each subject in twenty trials was assessed and compared across the four conditions, considering the sex, the action and their subsequent interaction as fixed factors and the subjects as the random factor. The number of correct choices was analysed recurring to GLMM using a binomial distribution since the subjects could make a correct or wrong choice in each trial. The number of correct choices was compared also to chance level (10 correct choices out of 20 times) in each condition using a one-sample t-test.

The latencies time were analysed following a linear mixed model. Normality was assessed by analysing the residuals distribution through quantile-quantile distribution plots. Residuals proved not to be normally distributed as the correlation between sample quantiles and theoretical quantiles did not follow a linear distribution across y = x (**Figure 8 A** and **B** in **Appendix**). Hence, data was then normalized following a Box-Cox transformation where ($\lambda = -1$) meaning a 1/y transformation (**Figure 8 D** in **Appendix)**.

After transforming the data, it proved to follow a normal distribution as it can be observed by **Figure 9 A**, **B** and **C** (in **Appendix**). A linear mixed model was then applied to compare the latency values across the four experimental conditions.

Results were considered significantly different when $p < 0.05$.

3 Results

3.1 Number of correct choices

When analysing the whole sample, independently of sex and action factors, dogs did not perform above chance levels (10 correct choices out of 20) (t = 1.357, p = 0.178). Though, from the 46 dogs tested, 19 dogs performed above chance levels in both tests and 34 dogs performed above chance levels in at least one of the tests. An initial analysis with generalized linear mixed models using a binomial distribution found no significant effect of the sex factor (z = – 0.361, p = 0.718), the action factor (z = – 1.807, p = 0.071), and no interaction between these two factors (z = 0.136, p = 0.892). Since the interaction between the action and sex factors proved not to be significant, a new analysis was performed discarding their interaction. The sex factor remained with no significant effect (z = – 0.377, p = 0.706) meaning that the fact whether the sex of the partner dog matched or not the sex of the subjects did not have an influence on the subjects' following the cue and ultimately how subjects made their choice (**Figure 4**).

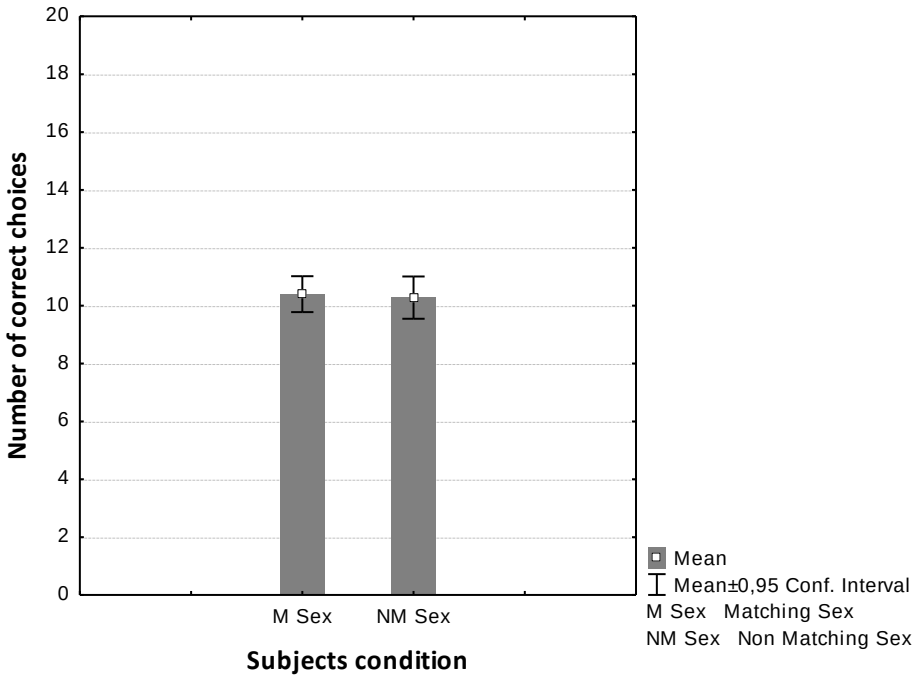

Figure 4 Mean number of correct choices made by the subjects in a two-way object choice task based on the gaze cue of a conspecific partner whose sex either matched (M Sex, N = 50) or not (NM Sex, N = 43) that of the subjects. No significant difference was found (see text).

On the other hand, the action factor had a significant effect on the number of correct choices ($z = -2.355$, $p = 0.018$). In line with our expectation, subjects made a higher number of correct choices when the demonstrator dog had previously performed the same action as the subjects during the Imitation Recognition Phase (**Figure 5**).

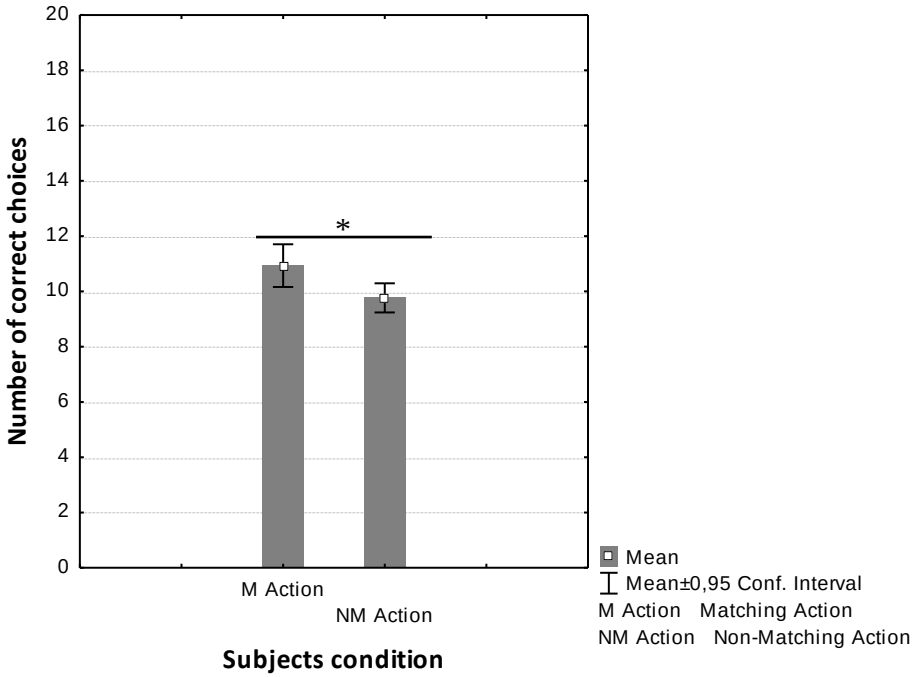

Figure 5 Mean number of correct choices made by the subjects in a two-way object choice task based on the gaze cue of a conspecific partner whose sex either matched (M Action, N = 45) or not (NM Action, N = 48) that of the subjects. No significant difference was found (see text).

Moreover, subjects in the matching action condition chose the baited bowl significantly above chance ($t(45) = 2.435$, $p = 0.017$). By contrast, subjects in the non-matching action condition chose randomly and thus their number of correct choices did not differ from chance levels ($t(47) = -0.893$, $p = 0.374$).

3.2 Latency

After transforming the latency data to reach normal distribution (see methods), both the sex factor and the action factor proved to have highly significant effects ($F = 16.7$, $df = 1832$, $p < 0.0001$) and ($F = 12.3$, $df = 1804$, $p < 0.0001$) respectively. Also importantly the interaction between the sex and action factors was highly significant ($F = 18.6$, $df = 1819$, $p < 0.0001$). Hence, both sex and action factors seem to influence the time that it takes subjects to make a choice and approach the target. By looking at each one of the factors independently it is

possible to discriminate which conditions contribute to the significance observed before. Namely, by setting fix one of the factors like for instance the non-matching action and looking only at the sex effect. This was done for every factor, matching action, non-matching action, matching sex and non-matching sex. Normality was once again accessed for each one of the fixed variables (see **Figure 10** to **Figure 13** in the **Appendix** for quantile-quantile distribution plots).

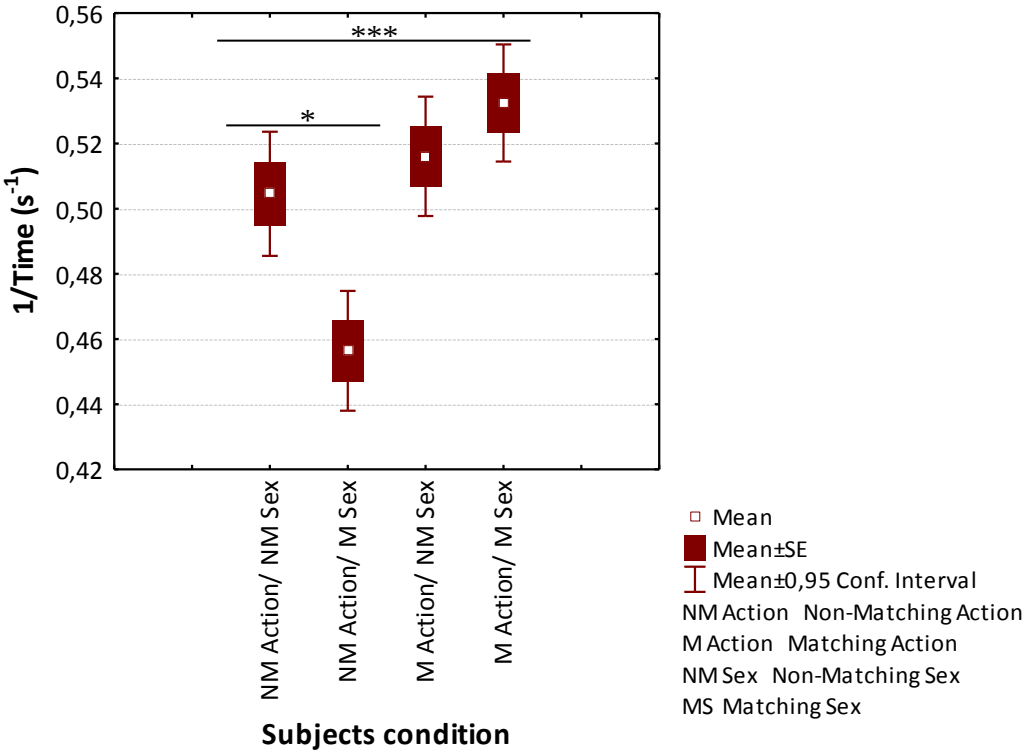

Figure 6 Box plot of the transformed latency values taken by subjects to make a decision in a two-object choice task for each one of the four possible experimental conditions, namely Non-Matching (NM) action/non-matching sex, non-matching action/Matching (M) sex, matching action/non-matching sex and matching action/matching sex.

When setting the non-matching action factor as the fixed one, significant differences were observed between the latency taken by subjects with matching versus non-matching sex (F = 6.45, df = 436, p = 0.01). Individuals belonging to the condition non-matching action/matching sex took longer to approach one of the pots (N = 538) when compared to individuals belonging to the condition non-matching action/non-matching sex (N = 400) (**Figure 6**). On the other hand when setting the matching action factor as the fixed one, no significant differences were observed between the matching (N = 459) and non-matching sex conditions (N = 440) (F = 1.06, df = 326, p = 0.3) (**Figure 6**).

Plus, when the non-matching sex variable is fixed, there are no significant differences between the latency taken to make a choice by individuals using the matching (N = 440) versus non-matching action (N = 400) (F = 0.13, df = 755, p = 0.7) (**Figure 7**). Finally, when setting matching sex as the fixed variable, significant differences were observed (F = 8.89, df = 922, p = 0.003). Individuals belonging to the matching sex/matching action condition take in general less time to approach the target (N = 459) when compared with individuals belonging to the matching sex/non-matching action (N = 538) (**Figure 7**).

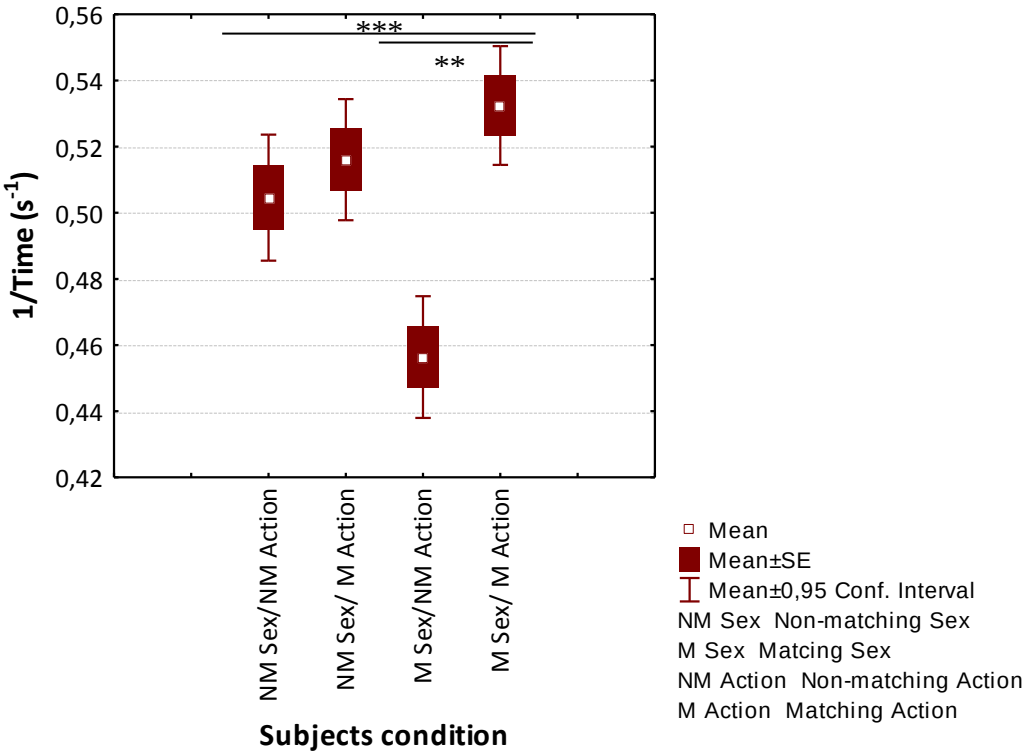

Figure 7 Box plot of the transformed latency values taken by subjects to make a decision in a two-object choice task for each one of the four possible experimental conditions, namely Non-Matching (NM) action/non-matching sex, non-matching action/Matching (M) sex, matching action/non-matching sex and matching action/matching sex.

Subjects take less time to approach one of the pots when they have to follow the gaze of a demonstrator that matched previously the action used by the subjects during the simultaneous working phase. Necessarily by contrast, if the demonstrator had previously used a non-matching action during the simultaneous working phase it seems to influence subjects to take a longer time to approach the pots. Although, previously the sex factor did not seem to affect the number of correct choices made by the subjects, it definitely affects the time that subjects take to make a choice. From, a preliminary overlook the subjects seem to take less time to

make a choice when the demonstrator does not match the subjects' sex. Though, the action factor seems to overlap this effect as the subjects belonging to the matching action condition are the one group of subjects that take less time to make a choice regardless of the sex.

Finally, dogs belonging to the matching action/matching sex condition group are the ones whose latency to make a choice is the shortest contrasting with the dogs belonging to the non-matching action/non-matching sex condition that take longer to make a choice.

4 Discussion

The results are in line with what was previously know from the literature (Hare and Tomasello 1999) as it provides evidence as dogs are able to follow social cues given by a conspecific, in particular following the gaze towards an attention focus such as a baited bowl. Moreover, this study goes even further since it provides evidence that the context and also previous interactions between dogs seem to affect the outcome and their performance in a two-way object choice task when they have the chance to locate hidden food based on the gaze cue of a conspecific. Dogs made a higher number of correct choices and also performed above chance levels whenever the gaze cue was given by a dog that had previously used the same action during former problem solving task where subject and partner worked simultaneously. Plus, dogs also belonging to the matching action condition were also the ones that took less time to approach one of the bowls. So far only humans and a few primate species are known to be able to recognize that they are being imitated. Additionally, only humans have been studied for the effect that imitation and imitation recognition foster between individuals, namely facilitation of social interactions, increased levels of connectedness and liking between people, closeness and mutual care (Iacoboni 2009). Nevertheless, dogs showed a preference for a social cue given by a partner that had imitated them previously and one can argue as well that dogs demonstrated an higher level of attention and cooperativeness towards this partner. Moreover, the fact that the dogs were previously imitated by a partner played an effect on how dogs paid attention to other social cues like following the gaze of another individual. Though, there might be other possible explanations, namely subjects might have a less agonistic behaviour towards the partner (for instance, being less agonistic about possible dominance by the partner over food resources), thus being more willing to approach the bowls. Another possible explanation could be due to the fact that even though dogs might pay a similar level of attention to partners that imitated or not previously, dogs interpret the gaze cue differently, thus depending on context. At this point it is possible to argue that dogs were really able to recognize that they were being imitated. Though, data should be further analysed, namely regarding the first phase of testing where it would definitely be relevant to measure the number of times and for how long subjects observe the partner. It is acknowledged that higher level of attention towards the imitator by looking more frequently and for longer periods is given as evidence for implicit imitation recognition (Nadel 2002). Hence, this would allow us to prove furthermore that dogs are able to recognize imitation. Nevertheless the context of ‘imitation’/’not ‘imitation’ affects the dogs’ outcome

when it comes to following the partner's gaze and choosing successfully the baited bowl and thus playing a relevant part. Confirming this is the fact that if the demonstrator had not previously matched the action used by the subjects, dogs chose correctly less times and performed at chance levels. Furthermore, dogs belonging to the non-matching action group also took longer to make a choice. Hence, although the previous results do not address directly whether if dogs have the ability to recognize that they are being imitated when they are working in the presence of another dog, one can argue that it positively affects the way that dogs perceive conspecifics in subsequent interactions.

Also interestingly, as verified in (Hare and Tomasello 1999) the sex of the demonstrator does not seem to affect the dogs performance when it comes to the number of correct choices. Significantly, the fact that the demonstrator matched the action used by the subjects during the simultaneous working phase seems to be the more relevant factor, as independently from the sex factor, subjects within the matching action condition had a shorter latency between being released and reaching one of the pots. Still, in the latency there was a sex effect: Nevertheless, it affects the time that it takes the subjects to approach and make a choice. In particular, the matching sex condition curiously has an antagonistic affect depending on if the demonstrator matched or not the action used by the subjects. Overall, subjects within the matching sex/matching action condition were the ones that took less time to make a choice whereas the subjects belonging to the matching sex/non-matching action were the ones that took longest to approach one of the pots. This fact could potentially be explained by intrasexual competition. In the literature it is possible to find some examples reporting it in dogs, such as the study done by (Cafazzo, Valsecchi et al. 2010) which addressed the dominance's relation to factors such as age and sex in free-ranging domestic dogs. The authors found that competition was higher between male dogs when food was involved than in the presence of receptive females and in the absence of sources of competition. Also importantly, the authors observed that also a higher level of competition was also displayed between females in the presence of food than in the absence of sources of competition. Therefore, the results of our study are in line with these previous findings. Though, it is important to stress that the sex effect seems to be overridden if the partner matched the subjects' action previously as it seems to promote affiliative behaviour.

Once again, this fact stresses the importance of how prior social experiences between dogs (although dogs did not interact directly during the experiment) affect their outcome in subsequent cooperative-communicative tasks. Dogs seem then to have a higher affiliation and

cooperation with a demonstrator that exhibits a similar behavioural repertoire when compared to demonstrator that does not match their behaviour. Hence, the previous results provides us a new insight of how dogs perceive and interact with other dogs which proves to be highly relevant since the literature mostly targets dog-human interactions, particularly when referring to cooperative-communicative tasks such as two-object choice task.

Many studies account for the outstanding performance of dogs in two-way object choice tasks when following the gaze of a human demonstrator e.g. (Soproni, Miklósi et al. 2001) when many other species such as the chimpanzee (*Pan troglodytes*) fail to do so. It is hypothesised that this readiness and attendance to human cues is probably a consequence of the domestication process that selected for this ability (Hare and Tomasello 2005) and also due to the fact that dogs are highly cooperative (Fitch, Huber et al. 2010). Since, this study contributes to show that dogs can cooperate in such a task with a conspecific, it sets ground to investigate the basis of why dogs can then be cooperative towards humans and apparently understand other human exclusive communicative signs such as pointing. Though, when the whole data sample was analysed independently of action and sex effects, results showed that dogs were not able to follow the conspecific gaze, although as discussed before dogs were able to do it but in close dependence to the social context and previous interactions. Furthermore, dogs seem to follow human cues independently of previous interactions. Commonly in experiments using pointing/gaze following, the dogs are not familiar with the experimenter and still are able to follow such cues successfully. Hence, this leads us to argue that dogs probably are more cooperative with humans than with conspecifics. It is important to mention though that the current study did not address the mechanisms underlying gaze following, that is, how dogs perceive it and what inferences they take from the gaze of others, like for instance assessing other's mental states or intentions (perspective-taking) or if it is singly reflexive. Additionally, it is not possible to address which areas of the body of the demonstrator are relevant for the subjects when following social cues like gaze, namely if it is only the eye region that matters or if the snout and mouth areas also play a part. This question can possibly be answered recurring to new technologies now available in canine cognition research such as eye-tracking systems (e.g. (Téglás, Gergely et al. 2012)) which allow to track the eye movement and fixation points when the dogs are looking at a particular target.

Also importantly, unanalysed data might provide more insight about other possible factors that might lead dogs to more affiliative behaviours towards conspecifics. As mentioned beforehand it would definitely be relevant to analyse the first phase of the experiment as it can

provide data regarding how much attention dogs paid to the partner. Hence, it would be possible to test if there is a correlation between the amount of time that the dogs spent looking at the partner during the simultaneous working phase with the dogs' outcome in the two-way object choice task. Therefore, one would expect that dogs looked longer at partners that matched the action and that these dogs were also the ones with higher number of correct choices in the two-way object choice task. Finally, since it is know that imitation tends to foster fondness between individuals, it would also be relevant to study the interaction between subjects and partner in a free interaction, namely to observe if dogs would tend to display more positive behaviours such as play, or even be more likely to mimic a partner that used a matching action versus non-matching action. Hence, a more thorough analysis of the data might help understanding the way dogs perceive other dogs.

As a concluding remark, this study is relevant since it takes the first step towards investigating the process of imitation recognition in an evolutionary distant species from our own and its possible implications over subsequent interactions between conspecifics. It also opens way to a better understanding of how social communication evolved prior to the advent of language, by exploring how the ability of following a social cue such as gaze of another individual (considered as a precursor to spoken language) in order to locate hidden food can be context dependent. Moreover, the way how individuals communicate/cooperate seems to also depend on prior interactions and social experiences.

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Appendix

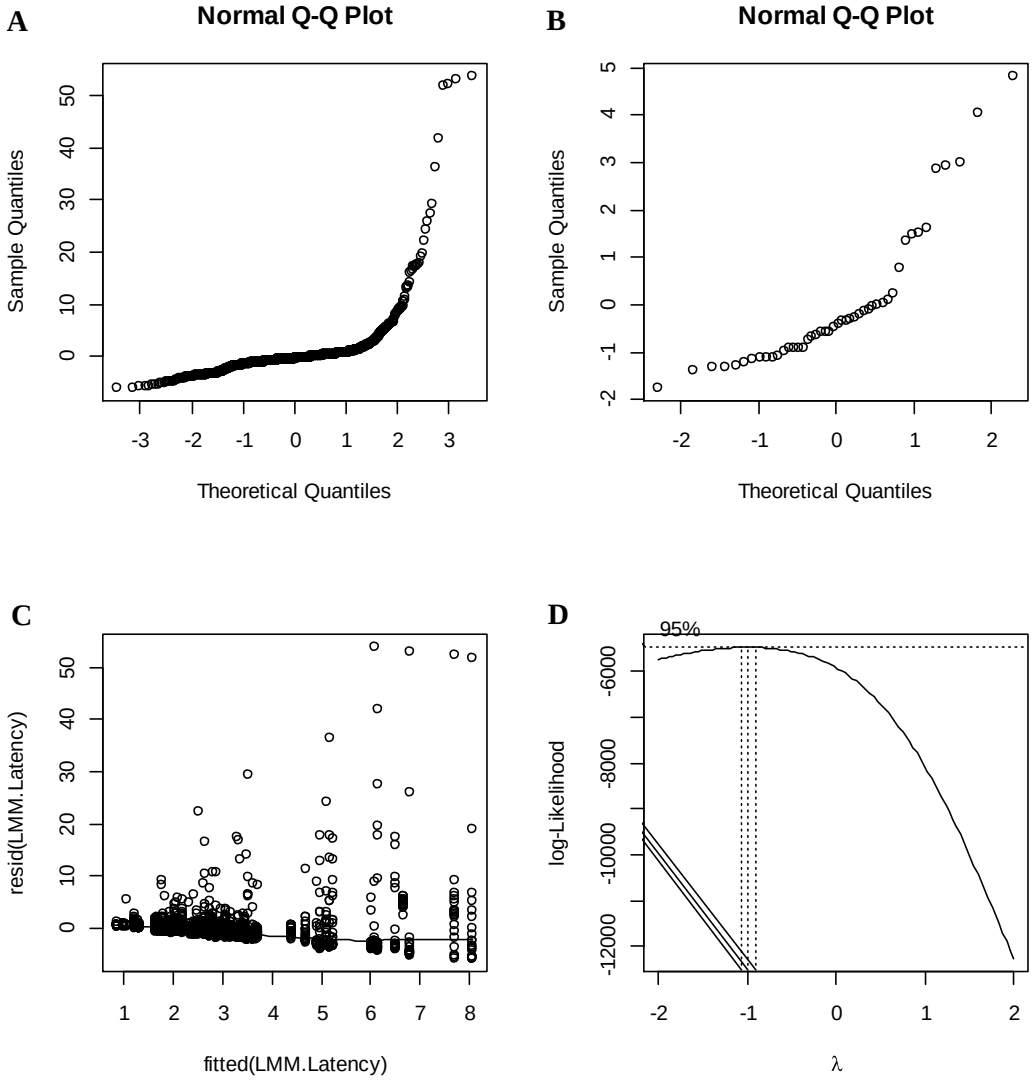

Figure 8 Analysis of the distribution of residuals regarding the latency taken by subjects to make a choice. Residuals do not follow a normal distribution (A) and (B) as residuals are not linearly distributed across y = x line. (C) Scatter plot with smooth curve fitted by Loess. Residuals are not equally spaced across the x range. (D) Box-Cox transformation ($\lambda = -1$).

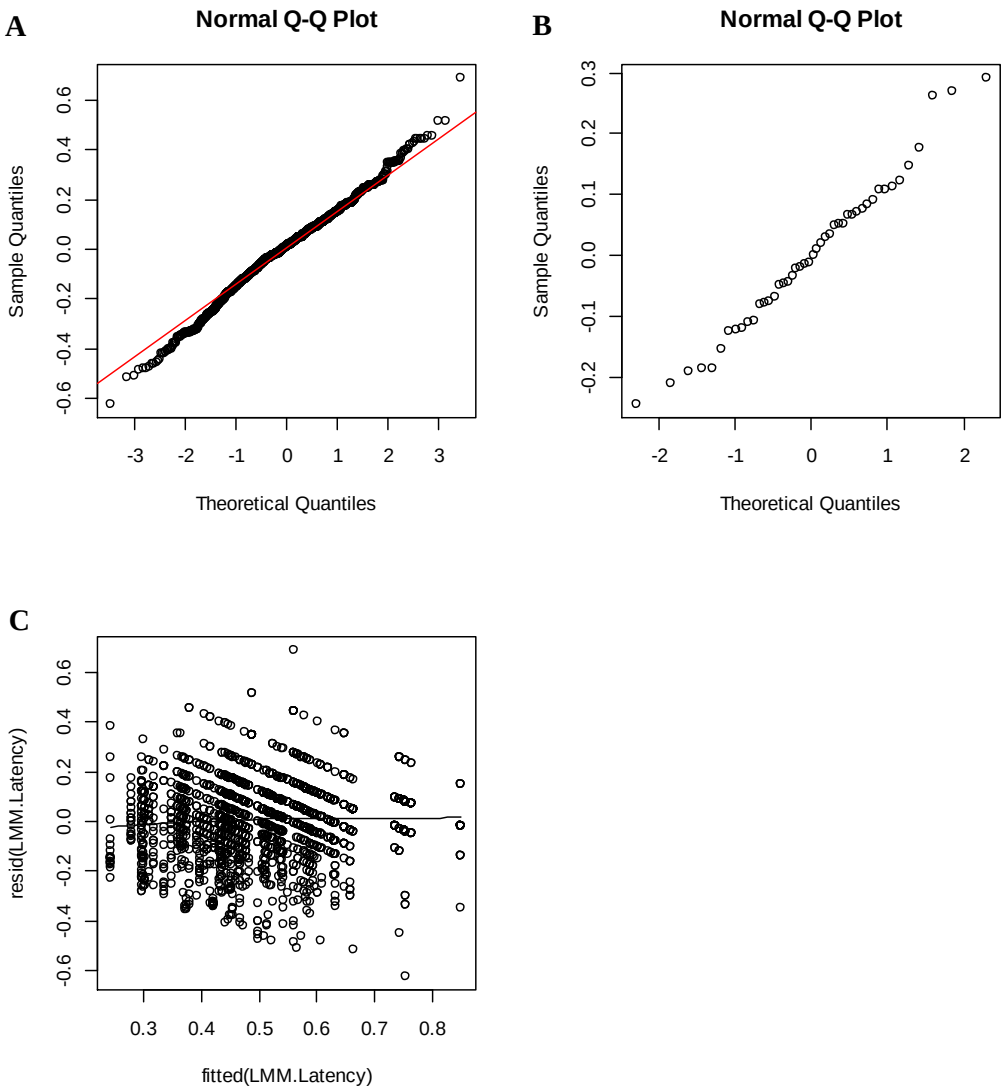

Figure 9 Analysis of the distribution of residuals regarding the latency taken by subjects to make a choice. Residuals follow a normal distribution (A) and (B) as residuals are linearly distributed across y = x line. (C) Scatter plot with smooth curve fitted by Loess. Residuals are equally spaced across the x range.

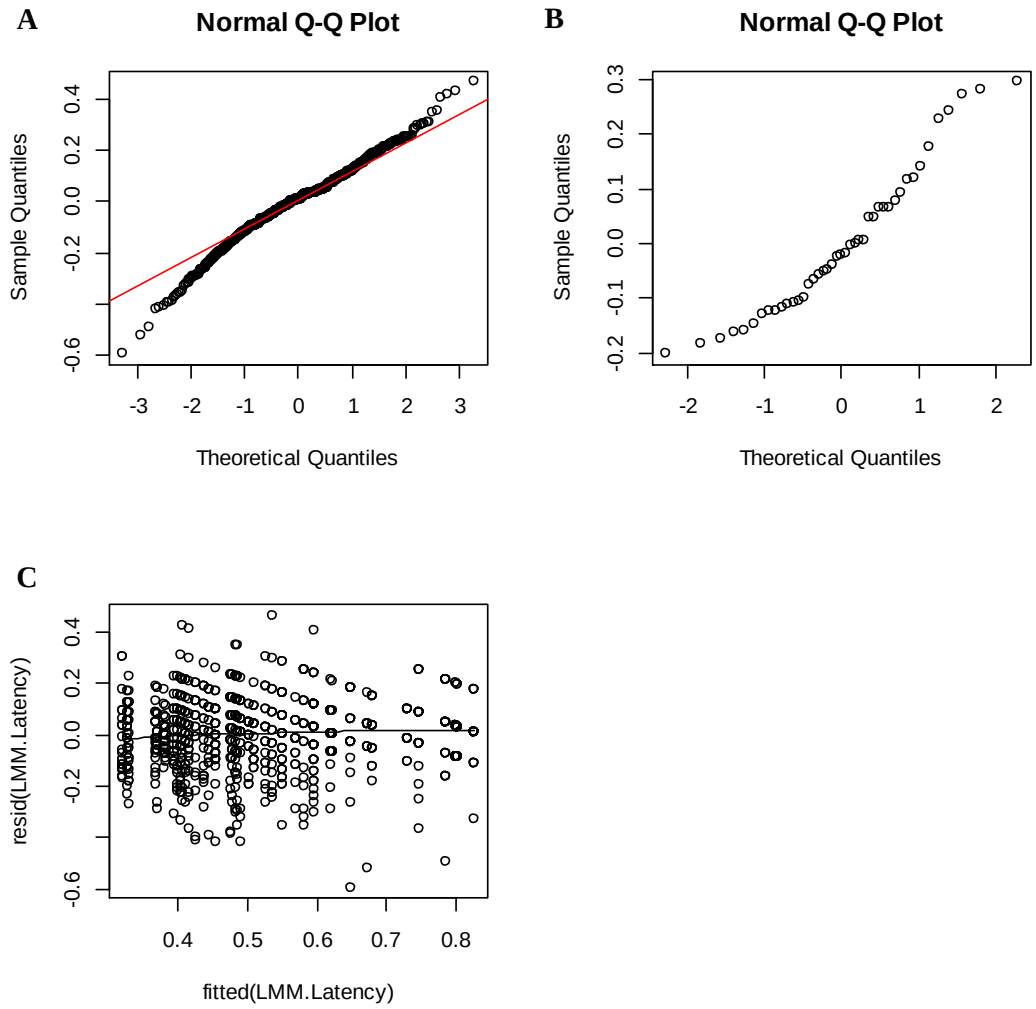

Figure 10 Analysis of the distribution of residuals regarding the latency taken by subjects to make a choice when non-matching action is the fixed variable. Residuals follow a normal distribution (A) and (B) as residuals are linearly distributed across y = x line. (C) Scatter plot with smooth curve fitted by Loess. Residuals are equally spaced across the x range.

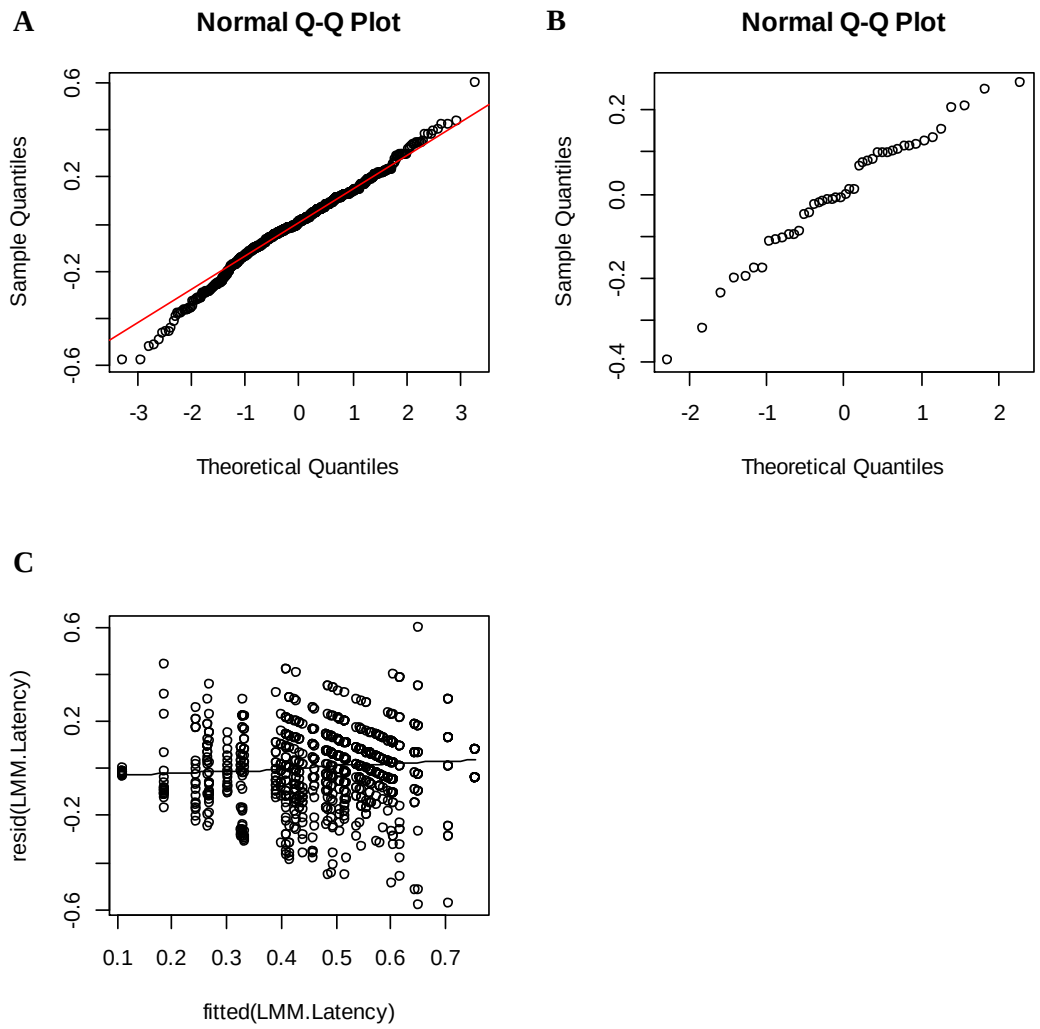

Figure 11 Analysis of the distribution of residuals regarding the latency taken by subjects to make a choice when matching action is the fixed variable. Residuals follow a normal distribution (A) and (B) as residuals are linearly distributed across y = x line. (C) Scatter plot with smooth curve fitted by Loess. Residuals are equally spaced across the x range.

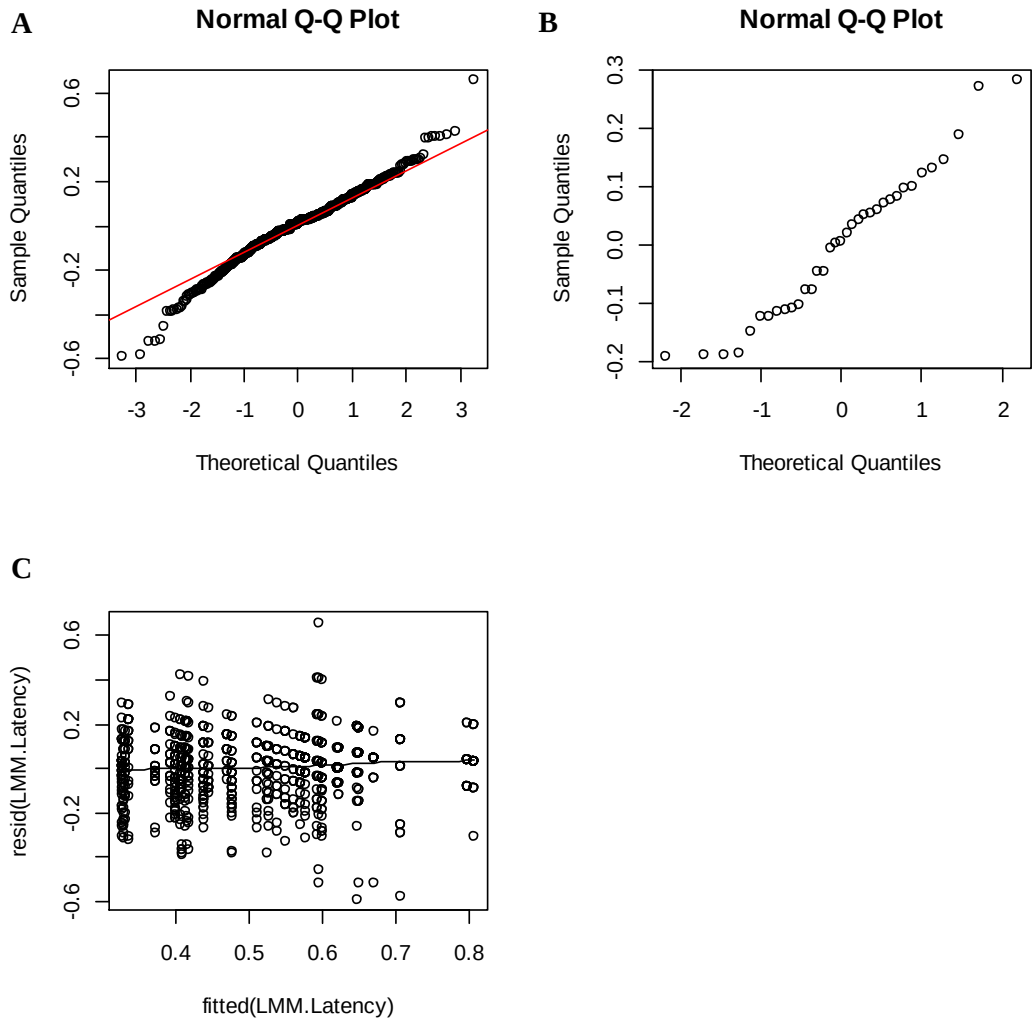

Figure 12 Analysis of the distribution of residuals regarding the latency taken by subjects to make a choice when non-matching sex is the fixed variable. Residuals follow a normal distribution (A) and (B) as residuals are linearly distributed across y = x line. (C) Scatter plot with smooth curve fitted by Loess. Residuals are equally spaced across the x range.

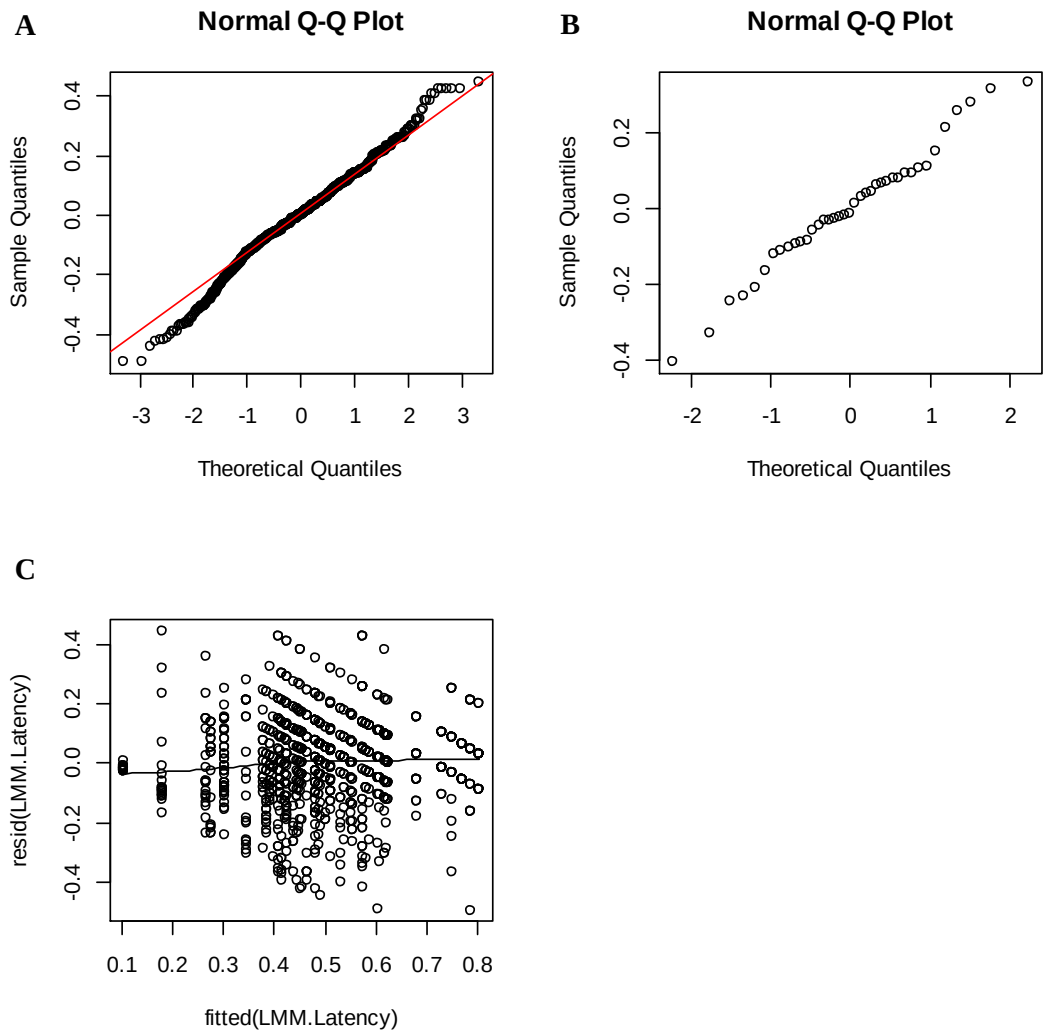

Figure 13 Analysis of the distribution of residuals regarding the latency taken by subjects to make a choice when matching sex is the fixed variable. Residuals follow a normal distribution (A) and (B) as residuals are linearly distributed across y = x line. (C) Scatter plot with smooth curve fitted by Loess. Residuals are equally spaced across the x range.